§ 41. Dusty Sheaths in Magnetic Fields

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Simulations of 1D magnetized dusty sheaths are carried out for plasma parameters close to ones measured in LHD (NIFS) divertor. 1) The plasma with the electron density $n_e \sim 10^{12}$ cm^{-3} and about equal electron and ion temperatures $T_e = T_i \sim 25$ eV consist of dust particles with radius $R_d \sim 3$ μm. The magnetic field $B_0 \sim 1$ T is directed on the divertor plate under angles $\theta \sim 45^\circ$ with the normal to the plate surface. Corresponding values of the electron Debye length L_{De}, the electron r_L and ion R_L, gyroradius, and its ratios are shown in Table 1. As can be seen in Table 1, the ion gyroradius R_L, exceeds essentially the electron Debye length L_{De}. Unfortunately, the density of dust particles is not known in the LHD divertor plasma (as well as in other fusion devices) although a surface mass density of dust collected from LHD was measured and consists of 0.1 – 0.2 g/m^2. 1) The maximum density of dust particles is chosen equal to 10^4 cm^{-3} close to the divertor plate. The density corresponds to the number of dust particles in a Debye cube $N_d = 1$, at which an influence of dust particles on non-magnetized sheaths is essential.

Typical results of computer simulations are shown in Fig.1 where the spatial coordinate x is divided by the initial Debye length $\lambda_d = (kTe/4\pi n_0 e^2)^{1/2}$. The results are shown at a condition that the number N_d of dust particles in a Debye cube is constant at $x < x_0 = 16$ and equal to $N_{d0} = 1$. The number N_d decreases according to $N_d = N_{d0} \exp(-(x - x_0)^2/w^2)$ at $x_0 < x < x_1$ where $w = 6\lambda_d$. Dust particles absent at $x > x_1 = 28$. The profile of the magnetic field B is given by $B = B_0 \exp(-x^2/a^2)$ where $a = 100\lambda_d$. Obtained results show that disturbance of ion and electron density is formed close to the electrode (wall) initially due to the ion collection. The disturbance transits continuously in the undisturbed plasma so that the disturbance wave propagates in the dusty region initially and than penetrates into plasma without dust particles converting into a rarefaction wave. The electrode (wall) potential ϕ_w changes initially very quickly and oscillates then. The potential ϕ_r on the right boundary is oscillating also but it remarkable changes only after an arrival of the rarefaction wave to the boundary. Simulations show that a ratio of oscillation amplitude to a mean boundary potential grows with an increase of the magnetic field and its angle with the normal to the electrode (wall) surface. Established spatial distributions of the electric field E divided by the characteristic electric field $E_0 = kTe/\lambda_D$ is shown in Fig. 1 by solid and dashed line for magnetized sheaths in cases with and without dust particles, respectively. As can be seen in Fig.1, dust particles decrease the electric field in the sheath and create an additional electric field close to a boundary of dust particles like to a sheath in an oblique magnetic field investigated earlier. 2) As simulations show, the increase of the magnetic field or its angle with the normal to the electrode surface causes the decrease of the electric field in the magnetized sheaths.

Reference
1) Sharpe, J.P., et al., J. Nucl. Mater. 313-316 (2003) 455.
2) Chutov, Yu.I. and Kravchenko, O.Yu., J. Plasma and Fusion Res. SERIES 3 (2000) 558.

L_{De}, cm	r_L, cm (for e)	R_L, cm (for H^+)	r_L/L_{De}	R_L/L_{De}
3.7×10^{-3}	1.7×10^{-3}	0.08	0.46	21.6

Table 1. Electron Debye length L_{De}, the electron r_L and ion R_L, gyroradius, and its ratios in LHD.

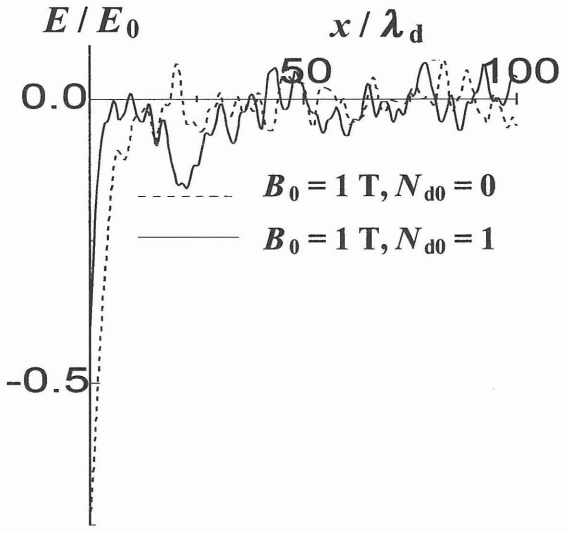

Fig. 1. Spatial distributions of electric field for magnetized sheaths without dust (dashed line) and with dust (solid line).